This article is a revised version of the first of three articles published in the Colorado EMSAC Star during 2011 and should be read in conjunction with the 3rd Annual EMS Safety Summit conference presentation available on the Ambulance Visibility website

On stage one evening the talented actor Dudley Moore mused about road safety. He ended his dialogue by delivering a tongue in cheek punch-line, *"the best car safety device is a rear-view mirror with a cop in it."* I agree with him but these days across America it is getting harder for the driving public to easily spot police cars. The nations' police departments have taken a step back in time and begun patrolling in vehicles displaying the old-style black & white markings – or what we now recognise as camouflage markings. This shift to the traditional two-color paint scheme is a winning strategy for accomplishing the latest aims of community 'high-visibility' policing programs. However, the strategies of high-visibility policing that are so actively promoted by neighbourhood safety programs have become confused with a different visibility strategy; that is the set of guidelines intended to enhance visual conspicuity on the nation's emergency vehicles.

Accident rates and tradition are driving conspicuity in different directions

The widespread return to traditional vehicle colours is not restricted to police in the United States. There are numerous Fire Departments around the world that have canvassed staff for their opinions and as a result, are once again painting their appliances fire-engine red. EMS agencies are returning to the older and less conspicuous range of body colors that today include blue, brown, green and purple. Even more surprising is the recent trend towards painting ambulances and fire trucks in stylish gloss black; all these darker colors have been shown in a Monash University (Australia) study[1] to increase the risk of an accident.

Figure 1 - A Black & white police cruiser on a city street appears half-hidden in the shadows

Over the last few years America has stepped up the search for solutions to combat the steadily rising number of accidents involving EMS vehicles. Enhanced vehicle conspicuity markings are now seen as a part of the total solution. The interest of American emergency response agencies peaked in 2009 when the landmark FEMA Emergency Vehicle Visibility and Conspicuity Study[2] was released and again with the controversial NFPA 1917 Draft Specification document for Ambulance Vehicles[3]**.** These key publications have already played an indirect role in the move away from established research by embracing popular generalizations and viewpoints[4]. Both reports include new design provisions that support the use of as-yet-to-be-proven marking patterns such as the inverted-V chevron pattern. These imported European marking schemes have already been adopted by agencies in the United States. The so-called safety patterns are often misconstrued, modified and then misused without any validation, testing or shielding legislation.

So how do we define visibility, conspicuity and recognition?

There is a great deal of confusion about the meaning of these terms and they are often used incorrectly and interchangeably. This frequently leads to misinterpretation; here are some easy definitions that hopefully will clarify the situation.

1. Physical Conspicuity is described as the *'ability of an observer to detect a target in a brief presentation'* (Engel, 1977). It measures the propensity of an object to attract attention (see Langham & McDonald - also Olson, 1996). Physical conspicuity relates directly to the both the vehicle body colour and shape, as well as any markings that are applied to the vehicle.

2. Cognitive conspicuity refers to the human aspects of viewing the emergency vehicle and the mental processes that organize the information and initiate the observer's response. Breakdown of the cognitive process plays a major part in *Looked But Failed To See (LBFTS)* accidents where drivers collide with emergency vehicles despite the prominent display of markings and lights[5].

3. Visibility measures the ease of discrimination of an object with a known location (Langham & McDonald). Here is an example of low visibility – a camouflaged vehicle that is just visible among trees - you may be able to discern it within your field of view, but you cannot accurately visualize the actual size or shape of the vehicle.

4. Recognition describes the ability of an observer to attach meaning to particular shapes and colors. The popular Battenburg or chevron markings may be considered as recognition patterns, however only one or two of the latest recognition patterns can be accurately labelled as high-visibility markings. You can identify fire trucks by their unusual shape but recognition can actually take longer if the popular but ineffective types of 'visibility' markings disguise the vehicle outline. It is very easy for haphazard designs and motifs to induce camouflage effects whenever the vehicle is viewed against a complex cityscape or in low-light situations. Any visually confusing feature on a vehicle will actually increase the time required for the viewer's cognitive functions to analyse the subject detail, plan a response, and then react, all within good time.

Figure 2 – Chevron "visibility" markings combine with a red/white color scheme to effectively camouflage a fire appliance, making it difficult for drivers to quickly determine the size, shape or orientation of the vehicle.

Five factors of awareness that add-up to superior vehicle CONTRAST

Emergency vehicles need to satisfy five important criteria to inform and guide a timely, appropriate and much safer response from road users. The use of the words "inform & guide" in the preceding sentence are by no means accidental. These factors impart environmental contrast information that assists other drivers to avoid an emergency vehicle. These important factors are as follows:

1. Motion/Speed: Fast-moving vehicles will usually be seen earlier if they stand out against the slower vehicles around them or if they are seen against a plain background. The vehicle speed also determines how much time is available for the decision-making process and collision avoidance.

Figure 3 – The fluorescent waistline stripe, red baseline stripe and white contour markings combine to accurately & rapidly inform other drivers of the shape, size and orientation of the emergency vehicle

2. Apparent visual size is used by all drivers to calculate separation distance and the rate of closure between vehicles. A vehicle gets larger as it approaches and this increase in the visual size of a closing target is called 'looming'; the larger the target and the closer it is, the more likely it is to be seen. The reflective markings on your vehicles should be carefully designed so they enhance, rather than hinder the discrimination of effective size.

3. Shape communicates both the type of vehicle and vehicle orientation. It is important to include contour markings so the vehicle perimeter is effectively outlined and clearly visible at night. A vehicle with a different shape will usually stand out amongst a group of unlike vehicles.

4. Color: Certain colors, especially yellow and yellow-green will be seen faster than darker colors when viewed against common landscapes or complex cityscapes. Large panels of color or broad stripes that contrast against local backgrounds can be seen easily - fluorescent colors really stand out!

5. Brightness: Fluorescent, reflective and other bright colors assist in differentiating an emergency vehicle from the pack of nearby vehicles and the background landscape. For fluorescents, this effect is maximised at dawn/dusk, during adverse weather conditions and under any low light conditions.

These five factors convey emergency vehicle location, orientation & intended course

How do you recognize if an emergency vehicle is stationary, approaching, passing, crossing laterally or moving away? It is essential that the factors listed are integrated onto the vehicle with a number of artificially created visual markers. These markers plus other key features displayed on an emergency vehicle communicate important optical clues to the viewer. Emergency vehicle marking layouts should proffer an unambiguous visual profile that swiftly reveals any change of intention or alteration of the vehicle direction to surrounding drivers. Agencies should deliberately choose bright colours that enhance the apparent size of the vehicle and entice the viewer's attention. The inclusion of well-designed reflective/fluorescent markings will emphasise the shape and form of your vehicles, passively working to lower the risks to personnel and help mitigate damage to vehicles in accidents.

The impact of fluorescent colors

Emergency vehicle body colors and marking designs must be effective during daylight (photopic), darkness (scotopic) and under the artificial lighting that illuminates our cities and roadways at night. Human vision attains its maximum sensitivity at 555 nanometres (nm) in daylight and at 507nm when our eyes have become dark-adapted at night. These peak wavelengths are located in the yellow-green region of our colour vision. This explains why our attention is drawn to the bright yellow-green paints such as American DuPont Imron Lime-yellow or the European color equivalent, RAL 1016. Dr Stephen Solomon[6] confirmed the efficacy of yellow-green after he demonstrated the lower accident rate of lime-green fire trucks when compared to similar red and white fire trucks in the Dallas study[7].

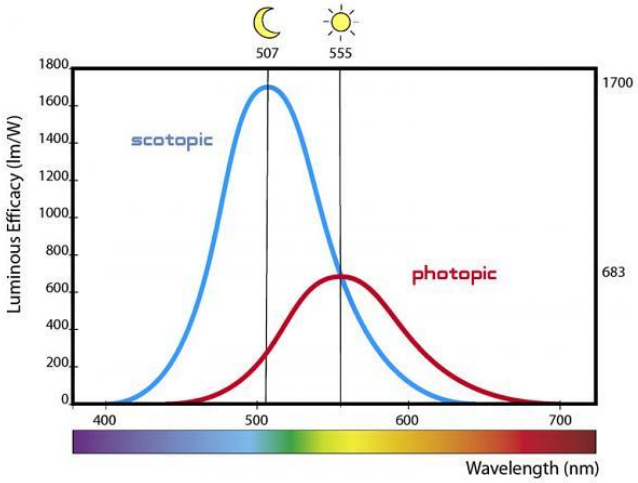

Figure 4 – Visual response of the human eye day & night with the daytime response peaking at 555nm in the yellow-green wavelengths - Note the move to 507nm and to blue-green at night (the Purkinje shift)

Stabilised fluorescent color pigments and micro-prism technology developed in the mid-1980's made it possible to design new high-visibility fluorescent/reflective marking schemes for emergency vehicles. The latest materials are significantly brighter in both daylight and darkness. These bright colors are highly effective for attracting viewer attention towards vehicle targets located within the central and peripheral fields of human vision (especially in the older age groups with deteriorating vision). Solomon proved that a green-yellow vehicle approaching from the side attracts viewer attention in the peripheral regions much earlier and at a greater viewing angle than a red and white vehicle[8].

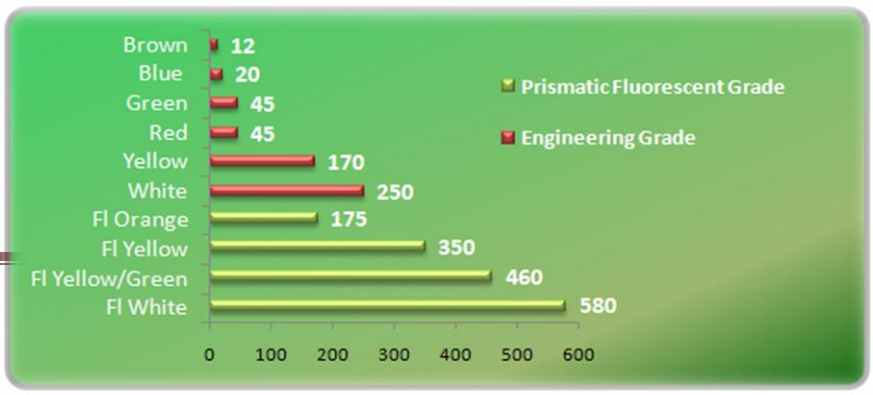

Figure 5 – Reflectivity of prismatic and engineering grade reflective materials measured in candelas. This graph clearly demonstrates how dark colors waste the retransmitted reflected light.

Picture frame visibility versus real world accident scenes

The first point I made in the presentation to the 3rd Annual EMS Safety Summit held in Colorado (October 2010)[9] was the tendency for emergency agencies and their chosen graphic design teams to create a new vehicle marking scheme and then examine the vehicle as if it was located in a framed photograph displayed on an office wall. In this scenario the vehicle stands alone with its colourful markings and complex patterns against a painted background totally devoid of detail. This isolation effect disappears when the actual vehicle is turned out for everyday operations. It's now working around vehicles or personnel from different agencies that display a varied range of patterns & colors.

It is essential that personnel and vehicles can be visually differentiated and separated from the total visual mass of the entire incident scene. Drivers in cars approaching a road accident must be able to rapidly weigh-up the scene ahead and negotiate a safe path through or around the incident. Dr Stephen Solomon made a valid point when he stated, *"anything that lengthens reaction times increases the chance of an unwanted event."*

Figure 6 – A mix of different vehicle markings at an accident scene can be visually confusing to other motorists

EMS organizations should go on-road and periodically assess the physical conspicuity of their vehicles, the clothing of their personnel and how they interact with the vehicles and clothing of other agencies when they are all operating together. This type of subjective assessment should be undertaken by every participating agency across several different incident scenes. Managers from each agency should collectively endeavour to eliminate the operational pattern and color conflicts.

The Ambulance Visibility Ten-point Markings Toolkit

There has been a huge amount of technical research completed over the last twenty years, however little emphasis has been placed on converting the findings into functional strategies for response agencies marking-up their vehicles. The following list provides ten practical and easily understood guidelines that will maximise the conspicuity, visibility and visual safety of your agency's vehicles.

1. Choose a vehicle colour that has maximum contrast against the local landscape

Consider all the colours of the landscapes within your local area of operations. The choice of vehicle colour becomes more difficult for complex urban landscapes or cityscapes, especially if an agency provides services within both city and rural environments. Make sure your chosen colour will suit all the vehicle types in your fleet, including ATV's, boats and aircraft. By default, yellow-green, chrome yellow or the European RAL 1016 paints are ideal for maximising visual safety as the bright colors match the peak sensitivity of the human eye. Vehicles with a complex appearance should be painted one colour to maintain form and singularity. White is a suitable safety color only when partnered with bright fluorescent materials. It may seem fairly obvious to avoid using white vehicles in snow regions but if you have no choice (or are retrofitting older vehicles that are white) then the application of large fluorescent panels or wide stripes is an effective option.

Figure 7 – Ambulance painted in high-conspicuity yellow-green paint

2. Add wide reflective/fluorescent stripes or whole panels of colour

I am sure over the years everyone has seen an emergency vehicle with the customary two inch reflective stripe running along its length plus a few words of text on the sides. This layout is easily overlooked andis of little help communicating the size, shape or length of the vehicle to an observer. By comparison, a broad waistline-height stripe in a single color is easily seen by drivers looking through the windscreen and side windows of their car. High roof-line stripes remain visible while moving through heavy traffic and a colored panel on the hood will attract more attention in rear-view mirrors. The bright stripes very quickly deliver information about vehicle length and height to other drivers. Arched cut-outs over the wheels project and reveal the total size of the vehicle and any change-of-direction as the orientation of the arched silhouette changes.

Figure 8 – An effective fluorescent and reflective multi-level layout applied on a white base color

3. Outline the vehicle using reflective contour markings

If there was a single change you could make to improve the conspicuity of your vehicles, then adding contour markings to enhance visibility at night will reap the greatest benefit. Outlining the shape of the vehicle sends out detailed information about vehicle size, purpose and direction of travel. Minor positional changes in vehicle direction will be quickly noticed by other drivers. Contour markings measuring just one or two inches wide are simple to apply and relatively inexpensive. The combination of wide waistline stripes and contour markings are vital for achieving effective conspicuity. Contour markings are easily retrofitted to existing fleet vehicles for little cost.

Contour markings should be visible from the front, back and sides so they completely outline the vehicle shape. Vertically oriented contour stripes provide even more valuable information by assisting the viewer to decipher minute changes in apparent size, distance and orientation. Ideally, contour markings should be the same colour as the vehicle body so they do not complicate or break up the vehicle's profile during daylight hours. Contour markings are recommended by the FEMA conspicuity report.[10]

Figure 9 – Examples of different contour markings. Note the contour stripe color matches the body color and is therefore invisible in daylight.

4. Visually balance all reflective/fluorescent elements to ensure the layout is effective both day and night

There is a very fine line between effective visibility and the patterns and colors fashioned in a visually overwhelming layout. The balance between body colour, reflective safety patterns and text must be assessed carefully. Red and blue reflective colors in close proximity to each other can cause irritating eye strain at night as the human eye repeatedly attempts to focus and refocus as it switches between the two different colours.

It is important to balance any mix of strong fluorescent colors. Select one dominant color and split away the other colors. The subordinate colors should be reduced in total area so they always remain inferior to the primary color. Reflected glare at night can also be a problem with overly large areas of reflective material. The total surface area should be trialled and then carefully reduced if necessary to prevent excessive halation or over-glow. Remember, contour or other markings can be intentionally color-matched to the vehicle color so they remain invisible in daylight but will reflect clearly under headlight illumination at night.

5. Building-in visual cues to enhance viewer perception

Complex patterns will often disguise the vehicle's profile. Major vehicle features should remain plainly visible, thus helping other drivers to anticipate your route, react to any directional changes or just as quickly calculate a closing distance. Angled stripes or repetitious patterns can visually break the vehicle into disjointed segments. Inverted-V chevrons extending to the corners of the vehicle profile can blur the viewer's discrimination of the bodywork edge. Vertical reflective stripes along the four corners will help other drivers to calculate changing vehicle distances and speed at night.

A broad waistline stripe should be always be positioned so the semicircular cut-outs over the wheel arches obviously protrude into the marking material. These cut-outs increase the capacity of other drivers to gauge size, distance and orientation of the vehicle as it moves through traffic. Some states legislate that certain colors must always be fitted eg. red reflective must appear only on the rear of vehicles. The drivers in these states learn over time to quickly identify vehicle orientation by recognising a particular color.

Figure 10 – An ambulance SUV displaying visual cues to assist recognition and an ambulance with half height chevrons & oversized text decaying to clutter

Roofline stripes are designed to be easily seen above traffic and are readily integrated into any overall contour marking layout that fully encircles the vehicle. Door-frame markings should also be integrated as part of the contour layout. This effectively reveals any doors left open at the scene. Open doors immediately suggest that personnel are working around the vehicle. Some Australian agencies use a fluorescent red/orange baseline stripe (Figure 10) to enhance recognition over longer distances (often much greater than 700 yards) and to increase vehicle visibility during occasional snowfalls. Finally, vehicle markings that have been carefully designed to silhouette personnel working around the vehicle are superior. Avoid any confusing oversized text or marking layouts that may overwhelm the senses and as a result will tend to camouflage personnel working nearby (see the headline photo).

6. Eliminate complex graphics, designs or patterns from your layout

The truly conspicuous high-visibility designs are simple, clear and easily understood. Designs that include large images, graphics, angular lines, complex patterns, alternating colors or oversize text all add together to create visual camouflage. For example, Canadian research[11] has proven that the NHTSA alternating red/white 'conspicuity' pattern for heavy vehicles in the US is inferior to a solid yellow or plain white stripe under most weather conditions. In the same way, the Full Battenburg high-visibility checker pattern[12] used by the British emergency services on high-speed motorways was found during testing to be less effective within a complex urban environment. Subsequently, the simplified Half Battenburg design was created for use on vehicles working within built-up areas:- use Battenburg with care.

Figure 11 – A complex hybrid design akin to camouflage. It is not Battenburg, not high-visibility and definitely not safer.

Figure 12 - Half Battenburg

You should also be aware that the value of the rear-facing inverted-V chevron pattern adopted by default in the UK has never been independently assessed or tested. The chevron design has been embraced by many national agencies along with standards organisations, mostly on the hearsay of popular opinion. The traditional Sillitoe pattern (small checkered squares) is not a high-visibility pattern at all. It is being hybridised by EMS and their favoured graphics firms into many different permutations, all described as 'a new era in safety markings'.

It is becoming clear that agencies need to remove any photo-murals, oversize Star-of-Life decals or agency logos, along with any checked, wavy or angular patterns on their vehicles to simplify their marking layouts.

Figure 11 - Australian multilingual emergency call icon

7. Rationalise & minimise all signage (text, logos

and badges)

After simplifying or removing any large-scale graphics mentioned in point six, turn your attention to rationalising any other signage displayed on your vehicle. It is impossible to read text or see badges clearly when the vehicle is moving - the general principles of sign-writing do not apply until the vehicle is stationary. Don't forget the population that you service is likely aged from one year to over 100 years of age, may speak many languages and each person will have a different level of education or reading ability; your marking visuals must be unambiguous and succinct.

Ask yourself, do I really need that particular line of text or the large logo? Can I make it smaller or reduce the number of words without affecting its clarity or purpose? If you operate in a region that requires your vehicles to display bilingual lines of text, then try substituting a more compact pictorial icon that embodies the same information. Icons can reduce the amount of text and substantially shorten the time needed to understand the message. Professionally drawn icons are readily available for Telephone 911, State, city or County flags as well as region of operations or particular skill levels. Large agency badges and logos combined with multiple lines of text often decay into vehicle concealment graphics. Just about all signage (except agency names or vehicle numbers) can be reduced in size to simplify the visual profile presented by your vehicle to those watching.

8. Use sentence-case and avoid over-sizing the text.

We have all seen an agency name on a vehicle printed in huge gold lettering. Oversized text covering large areas of a vehicle equates to camouflage when viewed at any distance. It has been proven in research that text using sentence-case (eg. Intensive Care Ambulance) is easier and faster to read, especially at longer distances. Letters in BLOCK CAPITALS tend to merge into each other at distance and reflective block letters are also significantly harder to read at night, especially for individuals with impaired vision. In Australia, the small area available for sign writing on the sides and rear of Sprinter van bodies has driven some states to cover most of the windows with large text and logos. This is a common error which can also obstruct the driver's view.

Figure 12 - Oversized text and logos corrupting the visual profile of a Sprinter ambulance. Compare this vehicle to the vehicle in Figure 8.

9. Design layouts and colours to assist the aged and visually impaired

The design of emergency vehicle signage often gives little thought to the many levels of visual acuity of different people within the community. As people age and especially after forty, their vision deteriorates significantly. Older drivers require higher levels of illumination to provide extra contrast, counteracting the slow onset of physical changes to their eyes. Many people continue to drive with untreated myopias, cataracts, glaucoma, diabetic retinopathy, macular degeneration or other eye diseases. There are also numerous drivers with color vision deficiency (color blindness). It is estimated at least ten percent of the population have deficient vision in some form.

The inclusion of fluorescent and highly-reflective prismatic materials, contour markings and any artificially visual cues will always assist the visually impaired driver in reducing their recognition and reaction times. Darker colours and patterns with lower luminance levels and reduced contrast tend to blend in and are not seen as quickly. Preservation of the whole vehicle shape by the designer is essential and any haphazard patterns that persist can produce considerable delays in the recognition of emergency

Figure 13 - Simulated comparison between normal and color deficient vision. Note only the centre ambulance retains high green-yellow luminance and the vehicle's appearance remains substantially unchanged

vehicles for both visually impaired individuals and those with normal vision as well. It is also worth noting that drivers who are marginally affected by alcohol or drugs also fall into the broad group of impaired drivers. It is imperative that the limitations of this group are taken into account during the planning phase of any emergency vehicle marking scheme.

10. Assess visual interactions of fleet markings with safety clothing & other vehicles

The close relationship between clothing worn by front-line personnel is directly interlinked with the vehicle marking schemes of your own agency and those of other agencies that co-respond. The nature of your surrounding landscapes and cityscapes are once again of major importance when considering protective clothing for your staff. While yellow-green safety vests may be the common industry choice, the color could be hazardous when worn in a region with a seasonal background of yellow leaves during Fall - a red/orange or two colour vest may be a better choice[13].

Figure 14 – A two colour safety vest with H-pattern white reflective tape. Note the long extended tail that provides extra visibility while bending down to treat patients

Several years ago when working on vehicle markings with Summit County CO it was decided the ambulances should be marked-up in yellow fluorescent material. This was in deliberate contrast to the lime-green safety vests worn by staff. Airport Fire Fighting and Rescue in Australia wear oatmeal coloured turnout gear in opposition to their yellow-green vehicles. Another option for night work use is to fit vehicles with reflective yellow markings while the vests worn by personnel shine a bright white.

If the opportunity arises to purchase new safety clothing, then this is the the ideal time to reassess the interaction between protective clothing and front-line markings, including vehicles from other agencies. Existing agreements between agencies about clothing colors may need to be honoured or renegotiated, but it is vital for the safety of staff that any color/pattern conflicts with vehicles from other local agencies are addressed.

Summary

Despite the increasing popularization of both traditional and strongly patterned ‘high-visibility’ markings for emergency vehicles, there remains a number of questions about the validity of these designs. The widely read FEMA Visibility and Conspicuity Study provided some reasonable but quite generalized options concerning the future of vehicle markings for US emergency agencies. Unfortunately, some of the broad statements made in the report have been misappropriated to substantiate alternative views, especially the viewpoints concerning recognition, vehicle color and chevrons. This has fuelled a popular push to mandate the as yet unproven ‘safety’ marking designs onto the nation’s emergency fleet. I will discuss these issues further in the next EMSAC Star article.

In the meantime, the Ambulance Visibility Ten Point Toolkit consolidates the available research into a set of functional guidelines for optimising your vehicle markings. Do not be concerned if the changeover to a new marking scheme takes time. The ACT Ambulance Service, despite the best of intentions, has taken just over five years to completely change the fleet markings on every vehicle. There is always plenty of time to contemplate proposed changes (both large and small) as you modify your design to fit any new body variations that will inevitably come along on your future vehicles. A major challenge for agencies in Australia was to successfully adjust the marking layouts to fit the unusual curves on the new-model Sprinter vans. As a consequence (just sometimes) Australians really do envy the Americans for the large flat sides on their EMS patient care modules.

More articles that will follow:

- Evaluating new trends - Advertising agency visibility, Chevrons and Battenburg markings
- The AV ten-point plan for optimising warning lights

If you need more detail, the hyperlinks & logos within this article will take you to the original research. An extensive library of links to research documents is available free-of-charge from the Ambulance Visibility Reference Library on the AV website – CLICK HERE

CASE STUDY

Improved fluorescent markings bring substantial savings to QAS

The Queensland Ambulance Service (QAS) in Australia covers a huge operational area of 670,000 sq miles with their staff responding to 751,000 cases last year. After consultation with the author and the Australian Capital Territory Ambulance Service in 2007, QAS decided to change the reflective markings on their fleet of more than one thousand vehicles. The outdated and visually inferior red & blue markings were replaced with a new research based fluorescent/reflective high-visibility design that was similar to markings already in use on ambulance vehicles operated by two other interstate agencies. The impact of the change was immediate; the fluorescent colours provide enhanced safety for the crews and their patients while presenting a contemporary corporate image to the general public.

The most remarkable achievement of the QAS project was the considerable 30% cost saving realised by fitting improved fluorescent markings while switching to an enhanced LED warning light system.

Comments or questions about this article are welcome
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